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Intertidal zone of Svalbard

1. Macroorganism distribution and biomass

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Summary. In summer 1985–1991, the intertidal zone of the Svalbard archipelago was sampled in 242 localities. Thirty seven taxa of macrofauna and 22 of macrophytes were considered as littoral zone inhabitants. Four major littoral assemblages are described: *Fucus-Balanus*, *Gammarus*, *Onisimus* and Oligochaeta communities. More than 80% of the investigated coast is occupied by the Oligochaeta assemblage with mean biomass values less than 1 kJ/m². The richest benthos was found at *Fucus-Balanus* sites (8% of the coast line) with biomass values exceeding 2000 kJ/m². The southern tip of Spitsbergen is part of a major zoogeographical border in the littoral fauna distribution. Subarctic species like barnacles, periwinkles and *Gammarus oceanicus* predominate on the western coast whereas, on the Arctic East coast barren beaches, *G. setosus* predomination was found.

Introduction

The Arctic littoral (intertidal zone) has been commonly regarded as deprived of life, because of ice scouring (Thorson 1936, Gurjanova 1957, 1963). This affects large parts of the Arctic, but the littoral may be fairly rich in many localities. Studies at such places were performed by Ellis and Wilce (1961) and Rozycki and Gruszczynski (1983). In recent years, the Arctic littoral has attracted renewed attention since oil drilling and inavoidable oil spills have become reality. Numerous impact studies have been prepared on the US and Canadian Arctic coasts (Cross et al. 1987, Owens et al. 1987). The mapping of littoral types was regarded as a very useful first step in coastal ecology management (Norton 1978, Mc Laren 1980).

Only a few papers have been published on the Svalbard littoral. The first were Summerhayes and Elton's (1923) ecological reports. Svendesen (1959) described the algal flora from Isfjorden and Feyling Hansen (1953) studied the biology of the barnacle *Balanus balanoides*. Ambrose and Leinaas (1988, 1990) and Hansen and Haugen (1991) presented some quantitative data from North West Spitsbergen. Legezynska et al. (1984) and Weslawski (1983) described qualitatively the littoral of the South Spitsbergen Hornsund fjord; shallow waters of Bear Island were described by Christiansen (1966).

The purpose of this study is to present an ecological inventory of the Svalbard coast and to map the areas of greatest biological importance.

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Material and methods

The littoral is defined as the area between high and low water marks. Littoral macroorganisms were considered as all those exceeding 1 mm in length and permanently (at least during summer season) living in the intertidal zone. That included both infauna and epifauna. Stranded, drifted organisms, as well as those dwelling in the littoral only during high tide, were not included. Terrestrial organisms like Acarina and Insecta were disregarded. South Spitsbergen National Park (SSNP), South East Svalbard National Reserve (SESNR) and Isfjorden were investigated in August 1988, 1989 and 1990 (Fig. 1). Sampling was conducted by two teams working simultaneously from inflatable boats. The total length of about 1400 km of coast was divided into 128 units, each of about 10 km length. Two to five sampling stations were located on each unit (242 stations are presented in this study). The selected stations were considered to represent typical sites for the given coast unit.

Each sampling station was investigated during low tide. The site was photographed and was allocated to one of 16 types of coast (Table 1). This simple classification was made by following general nomenclature used in the description of Arctic shores (Sempels 1982, Pulina et al 1987). The temperature and salinity of littoral water was determined at a depth of 0.5 m during low tide. Temperature was measured with reverse thermometers, salinity with a laboratory salinometer.

Macroorganisms were sampled from three squares of 0.25 × 0.25 cm, dug out with a spade on soft bottom or scraped with a knife from the solid substrate. The upper 3cm of the sediment were collected; subsamples were mixed together. Each sample was preserved in 4% formaldehyde solution in sea water. Samples were transported to the laboratory and washed afterwards on 0.5 mm mesh size screen. Retained organisms were sorted and identified under the stereomicroscope. Wet formalyne weight of sorted organisms was measured after gentle blotting of the organisms with

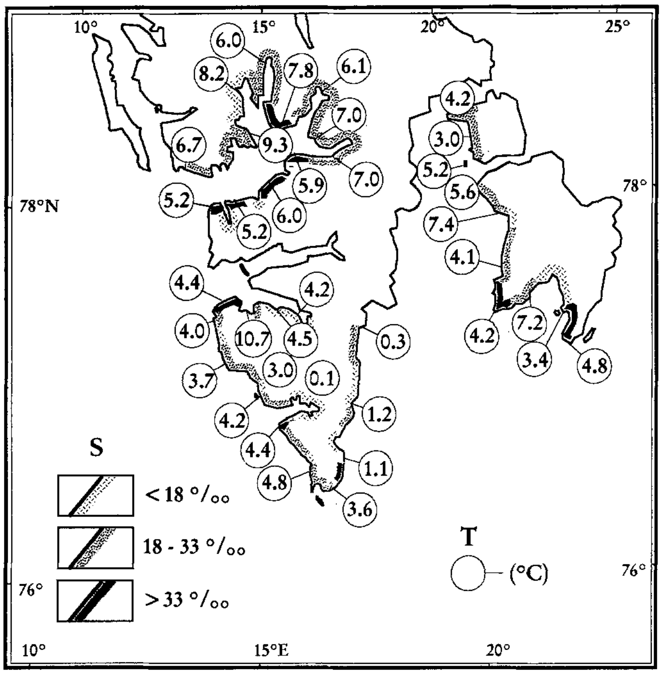

Fig. 1. Investigated coast line of Svalbard. Salinity (ppt) and temperature (°C) values observed in the intertidal zone in August 1988–1990

Whatman filter paper; they were weighed with 0.2 mg accuracy. Dry weight was obtained after drying the samples at 60°C for 48 h.

Plant coverage was determined at each sampling station from 7 squares each of $1 m^2$, and presented as mean plant cover on the given area. *Fucus* kelp length was measured from the base to the tip of live plants.

Additional collection of intertidal organisms was made at each sampling site with the use of a hand net in order to find species missing in quantitative samples.

Energy values were expressed in kJ after calculation from coefficients presented in Table 2.

The term "assemblage" was used to describe similar sets of organisms inhabiting similar types of coast. The scarcity of Arctic intertidal fauna and clear cut differences between different assemblages permitted the arbitrary description of collected material. There was little sense in performing any kind of multivariate statistical analysis in this case.

Other sampling performed during the present survey of Svalbard intertidal will be described in two other papers : Weslawski and Kwasniewski (unpublished work) – meiofauna, Wiktor (unpublished work) – phytoplankton.

Study area

The frequencies at which coast types occur in the investigated area are presented as percentage values in Table 1. The most common types were low gravel and sandy beaches, skjerra (coastal rocks) and glacier lagoons.

The tidal zone was usually 5–7 m wide, with the exception of some tidal flats which were more than 500 m in width. Tides were regular, moon M2 type, with a period of 12.42 h and an amplitude reaching 1.8 m at maximum (Siwecki and Swerpel 1975).

Ice has its maximum range in April. Then, most of the coastal waters are covered with fast ice which lasts for 3–9 months a year, depending on the locality (Weslawski et al. 1992). In summer, the western coast is free of ice, whilst the east coast is commonly affected by drifting pack-ice even in August (Vinje 1984).

Summer temperature of littoral waters ranges from below 0°C in the east to 10°C in the west coast tidal flats (Fig. 1). Salinities of littoral waters range from 0.5 ppt to 34 ppt in summer depending on the tide phase and local freshwater runoff (Fig. 1). High oceanic waves are common on the west coast in autumn; in fjords, short wind waves not exceeding 1 m in height are most common in summer.

Results

From 242 littoral localities a total of 59 taxa of macroorganism were identified (Table 3). The most diverse littoral was found at South Spitsbergen, the least at Storfjorden. The most frequent organisms were *Gammarus setosus, Fucus distychus* and large *Oligochaeta.*

All samples were classified to one of four basic assemblages/communities, clearly characterised by a dominant cluster of species:

– *Oligochaeta* assemblage – this community type occurred at localities where almost no macrofauna and flora were found. Biomass values ranged from 0 to 1 $kJ \cdot m^2$. Typical sites were gravel or sandy beaches with actively moving sediment and barren rocks exposed to ice and waves. In places with some detritus deposits, the macroscopic Oligochaeta (*Lumbricillus*) were common (Table 4). Oligotrophic coasts occupy more than 80% of the investigated area, especially to the North East (Table 5, Fig. 2).

– *Onisimus* assemblage – this consists of 10 species. Usually only one macrophyte species occurs: *Enteromorpha* or *Pilayella* (Table 3). This assemblage was found in brackish waters over a slightly stony soft bottom. Typical sites were tidal flats and moraine and glacial lagoons. The most numerous inhabitants were *Onisimus littoralis, Orchomene minuta, Gammarus spp*; where the sediment is more stable Annelida prevail. The *Onisimus* assemblage occupies more than 3% of the investigated coast (Tables 4, 5).

– *Gammarus* assemblage – this is characterized by a predominance of amphipods, with three other species noted. Vegetation is usually scarce: *Pilayella, Ulotrix, Chordaria*, a green film of filamentous algae or *Navicula* colonies. The phytobenthos cover did not exceed 10% of the area. Animal densities range from 50 to 10 000 $ind \cdot m^2$, biomass from 1 to 5000 $kJ \cdot m^2$ with a mean of 100 $kJ \cdot m^2$ at typical sites (Table 4). The richest *Gammarus* localities were found on sheltered beaches with large, loose stones. This community covers about 8% of the investigated coast line (Table 5).

– *Fucus-Balanus* assemblage – this is the richest in terms of diversity and biomass. Most characteristic are fronds of *Fucus distychus* accompanied by *Balanus balanoides, Littorina saxatilis*, juveniles of *Gammarus* and other amphipods. The composition of this assemblage depends on the presence of small habitats, like sheltered rock pools, amount of sediment among kelp rhizoids, etc. The faunal density ranges from 50 to 5000 $ind \cdot m^2$, biomass from 100 to 6000 $kJ \cdot m^2$ with a mean 3600 $kJ \cdot m^2$. This assemblage occurs on 8% of the investigated coast (Table 4, 5).

Biomass of the littoral was highest on the open oceanic coast, where in a few spots it exceeded 5000 $kJ \cdot m^2$. Eastern Svalbard and inner fjord basins were very poor in littoral biomass (Fig. 2).

Table 1. Different types of coast, that were distinguished in the investigated area of Svalbard

	SSNP	SESNR	ISFJORDEN
1. Steep rocky backshores without beach with loose boulders at the foot.	0.2	0.5	–
2. Steep rocky backshores with initial beach. Prominent avalanche cone of coarse material.	6.4	7.5	6.2
3. Rocky cliff with prominent abrasive shelf.	5.9	16.4	13.1
4. Low skierra with horizontal measures, covered with water at high tide.	1.9	–	–
5. High skierra built of folded rocks, often with vertical measures and coarse surface. Well above the high water mark.	16.1	–	1.8
6. Incoherent slate cliff with large abrasive shelf.	–	–	6.2
7. Boulders shore, originated after weathering and erosion of hard rocks, broken apart on semiregular blocks.	–	20.6	–
8. Glacier cliff.	15.9	0.5	6.5
9. Glacier lagoon, brackish water pond, connected with glacier front or its outflow, bordered from the sea by barrier beach.	1.6	3.9	–
10. Dead ice cliff, formed after the retreat of glacier which left large ice fragments, covered partly with moraine sediment. At the foot of dead ice cliff, narrow, initial beach occurs with coarse sediment.	0.1	–	–
11. Moraine beach, initial phase of the beach with erratics and occasionally fragments of old ice.	12.8	1.6	10.3
12. Watt – usually at the cone of river or glacier outflow.	4	3.8	6.9
13. River mouth with alluvial cone and well sorted sediment.	0.3	1.9	1.6
14. Low gravel beach with storm bar above high-water mark. Well sorted and pebbly sediment.	33.4	42.4	41.7
15. Steep stony beach with large, well punded stones.	1.4	0.9	–
16. Initial beach on alluvial cones and talus.	–	–	4.2
17. Artificial coast.	–	–	0.8

Occurrence of the *Balanus* and *Littorina* was restricted to the west coast. Barnacle was distributed wider than periwinkle (Fig. 3). *Fucus distychus* kelp length ranged from 3 cm on the east to 16 cm (35 at maximum) on the west coast. Phytal cover ranged from 0 to 10%, exceeding 10% at small local spots on the west coast (Fig. 4).

Discussion

In terms of morphology, the coasts of Svalbard are similar to those described for Greenland (Madsen 1936, Hopner Petersen 1962) or Baffin Island (Ellis 1953, Ellis and Wilce 1961). Steep rocky backshores without beach were the most common on the Eastern Canadian Arctic coast (Sempels 1982). The non – eroded skjerra common at West Spitsbergen were not that common in other Arctic regions. Water temperatures observed during the present study put Svalbard between Subarctic Western Greenland (summer temperatures up to 16°C, Hopner Petersen 1962) and high Arctic Franz Josef Land (at maximum −1.3°C, Swerpel 1992). There is only a little information on the salinity distribution and variation of Arctic littoral and typically large ranges of values are reported (Hopner Petersen 1966, Swerpel 1984).

From the taxa list presented in Table 3, more than ten might be regarded as newly recorded from the littoral of Svalbard. Since previous works on Svalbard littoral concentrated on algae (Svendsen 1959, Florczyk and Latala 1990) or soft bottom biota (Ambrose and Leinaas 1988), comparisons with older taxonomic lists are difficult. All species presented in Table 3 were known from shallow waters of Svalbard.

Compared to Table 3, the list of littoral species from Svalbard noted by other authors presents 13 more macrophytes (Svendsen 1959, Florczyk and Latala 1990). Am-

Table 2. Coefficients used for biomass calculations. Compiled from Percy and Fife (1981), Szaniawska and Wolowicz (1986), Wolowicz and Szaniawska (1986), with own unpublished data

Taxon	% of dry weight in fresh w.	$kJ \cdot g^{-1}$ (SD)
Fucus sp	17.5	14.4(0.57)
Chorda tomentosa	15	12.81(0.78)
Harmathoe	12	19.97(0.73)
Gammarus setosus	20	15.4(0.92)
Onisimus littoralis	23	16.87(0.4)
Balanus balanoides	25	10
Littorina saxatilis	25	8.37

Table 3. Macroorganisms found during the present study in the Svalbard littoral, n = number of sampling stations considered. Data show the frequency of occurrence in percentages, + species present in qualitative samples only. SSNP – South Spitsbergen National Park, SENR – South East Svalbard National Reserve

Taxon	SSNP n = 128	SESNR n = 25	ISFJORDEN n = 89
Verrucaria sp	5	+	+
Chlorophyta			
Acrosiphonia arcta	1.5	0	0
A. duriuscula	1.5	0	+
Ulothrix flacca	1.5	0	+
U. implexa	1.5	0	+
Urospora elongata	1.5	0	+
U. peniciliformis	1.5	0	+
U. wormskjoldi	1.5	0	+
Enteromorpha compressa	1.5	16	2
Phaeophyta			
Chorda tomentosa	2	0	1
Chordaria flagelliformis	2	0	1
Dictiosiphon foeniculatus	1.5	0	1
Ectocarpus siliculosus	1.5	0	+
Elachistia fucicola	1.5	0	+
Fucus distychus	30	20	21
Ilea zosterifolia	1.5	0	0
Pilayella littoralis	5	4	10
Dumontia incressata	1.5	0	0
Desmarestia aculeata	1.5	0	1
Bacillariophycae			
Navicula sp. colonies	2	0	2
Cyanophycae colonies	+	4	+
Actinia			
Thaelia sp	0.7	0	0
Oligochaeta, macroscopic	31	25	18
Polychaeta			
Harmathoe sarsi	1.5	0	2
Eteone longa	0.7	0	+
E. spetsbergensis	0.7	0	0
Ampharete finmarchica	0.7	0	0
A. acutifrons	0.7	0	0
Lumbrinereis fragilis	0.7	0	+
Scoloplos armiger	2	0	3
Spio filicornis	2	0	5
Pygospio elegans	1.5	0	+
Chone duneri	0.7	0	0
Fabricia sabella	2	0	3
Sabellides octocirrata	1.5	0	+
Priapulidea			
Halicryptus spinulosus	2	0	3
Priapulus caudatus	0.7	0	+

Table 3. (continued)

Taxon	SSNP n = 128	SESNR n = 25	ISFJORDEN n = 89
Sipunculida			
Phascolosoma margaritaceum	0.7	0	0
Pantopoda	2	0	0
Nemertini	2	0	3
Crustacea			
Balanus balanoides	20	0	24
Anonyx sarsi	2	0	2
Orchomene minuta	4	0	+
Onisimus littoralis	4	8	13
Gammarellus homari	1.5	0	0
Gammarus setosus	16	28	58
G. oceanicus	20	0	12
Ischyrocerus sp	5	0	2
Calliopius laeviusculus	0.7	0	0
Weyprechtia pinguis	2	0	0
Gastropoda			
Margarites groenlandica	1.5	0	3
Cylichna occulta	0.7	0	+
Cylichna scalpta	0.7	0	+
Littorina saxatilis	6	0	16
Bivalvia			
Turtonia minuta	1.5	0	0
Macoma moesta	0.7	0	+
Liocyma fluctuosa	1.5	0	3
Pisces			
Liparis liparis s.l.	+	0	0

brose and Leinaas (1988) presented five more species of littoral Polychaeta, Summerhayes and Elton (1923) reported two Hydroids living in the intertidal zone.

The number of species found in the Svalbard intertidal zone is similar to that noted for Baffin Island and Greenland, where 30 to 50 species have been observed (Madsen 1936, Ellis 1953). The key species are common on most of the Arctic coasts. *Balanus*, *Littorina*, *Fucus* and *Gammarus* have been reported from Alaska (Feder and Kaiser 1980), Greenland (Madsen 1936) and Arctic Canada (Stephenson and Stephenson 1949, Ellis and Wilce 1961).

The clear cut differentiation of Svalbard littoral life permitted a simple definition of macroorganism assemblages. However, in many places, transistory assemblages could be found; in particular, *Fucus*- *Balanus* and *Gammarus* communities often occurred together. The *Gammarus* community described here has also been observed in the Eastern Arctic by Golikov and Averincev (1977) and Bushueva(1977). The tidal flats – *Onisimus* community was described as common on the Siberian coast (Gurjanova 1951). Polychaeta species found in Svalbard tidal flats (*Scoloplos armiger*, *Spio filicornis*, *Chaetosone setosa*) are the same as reported from the north Norwegian littoral – namely eurytopic and euryhaline forms (Sneli 1968). Oligochaeta were commonly reported as main faunal elements from soft bottom littoral in Greenland (Steven 1938). This is very similar to the "oligotrophic" Oligochaeta community described in the present study.

The range of biomass values in the littoral of Svalbard coasts (0.1 to 3000 g.wet weight m^2) is hard to compare with data from other sources, since only density data are

Table 4. Characteristics of macrofauna assemblages from the Svalbard intertidal zone

Community	Number of samples	Biomass in g wet weight (SD)	Density ind $\cdot$ m^2 (SD)	Mean energetic value kJ . m^2
Oligochaeta	97	$\geqslant 1$	$\geqslant 100$	$\geqslant 1$
Gammarus	68	17(20)	195(200)	40.5(47.6)
Onisimus	12	12.3(12.2)	192(188)	29(28.8)
Fucus-Balanus	65	717(752)	603(531)	1864(1955)

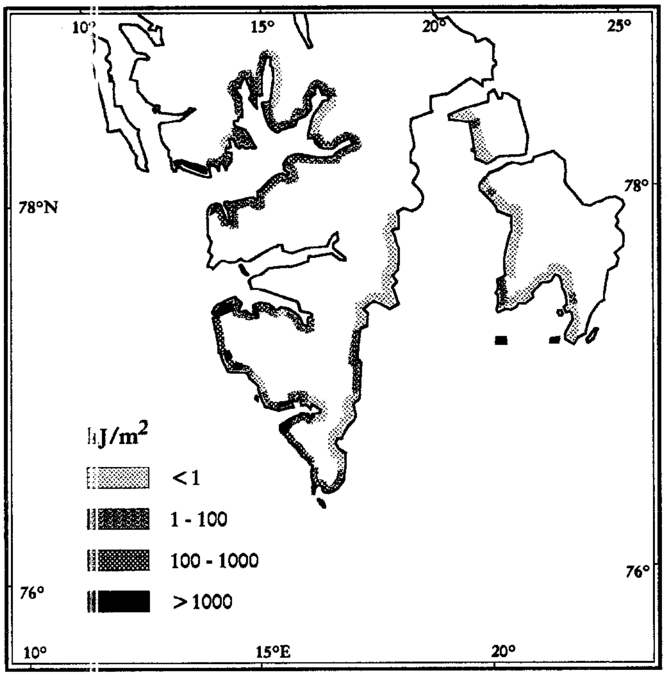

Fig. 2. Biomass of littoral macroorganisms, mean values for investigated coast units, August 1988–1990

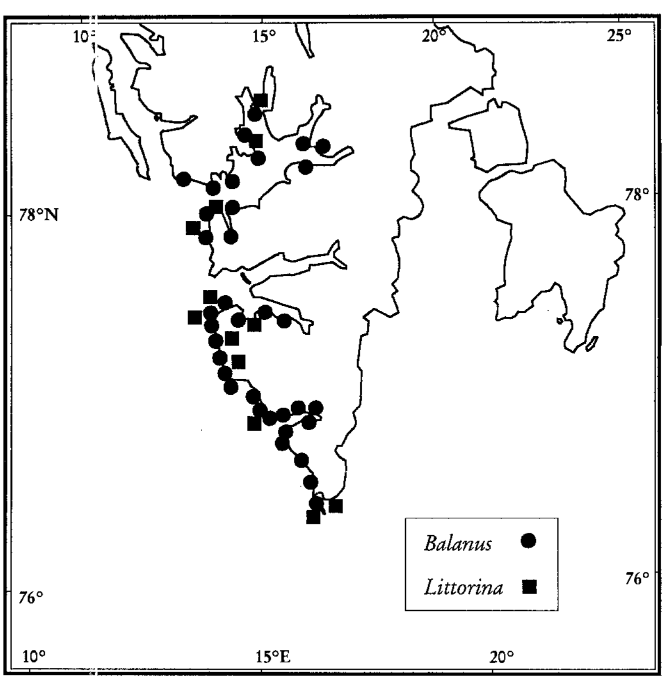

Fig. 3. Occurrence of *Balanus balanoides* and *Littorina saxatilis* in the investigated area, August 1988–1990

Table 5. Percentage of investigated coast covered with given intertidal assemblages. Abbreviations as on Table 3

Community	SSNP	SESNR	ISFJORDEN	Mean
Oligochaeta	70	89	85.5	81%
Gammarus	16	3	5	8%
Onisimus	2	3	4	3%
Fucus-Balanus	12	5	5.5	8%

available (Ambrose and Leinaas 1988, 1990; Hansen and Haugen 1991). However, the density of *Gammarus* from the Spitsbergen intertidal localities was similar to that reported from other Arctic sites (Bek 1990; Ambrose and Leinaas 1988, 1990; Weslawski 1992).

The set of species observed in the Svalbard littoral indicates its subarctic character. According to Madsen (1936), Dunbar (1949) and Ellis and Wilce (1961), the occurrence of periwinkles, barnacles and *Fucus* indicates a subarctic zoogeographical province. The mussel (*Mytilus edulis*), common in most subarctic littoral localities, is absent on Spitsbergen. That may indicate more severe conditions in the Spitsbergen subarctic province when compared to such areas in Greenland and Arctic Canada. Barren gravel and sand beaches with locally abundant amphipods are characteristic of the Arctic zone.

The border between the Subarctic and the Arctic province runs through Sorneset at the southern tip of Spitsbergen Island. The distribution of *Gammarus oceanicus*, restricted to the west Spitsbergen coast, shows this border as well (Weslawski 1992). The division into two zoogeographical zones is probably caused by temperature, salinity and the ice factor. Summer temperatures are only slightly different between east and west Svalbard littoral (+38 versus +3°C). The ice on the east coast lasts longer compared to the west, salinity is usually lower on the east. The east coast is also more affected by glacier outflow, with great sediment concentrations in the water (own observation). Feyling Hansen (1953) and Hopner Petersen (1962) have stressed the limited importance of ice as the limiting factor for the occurrence of *Balanus balanoides*. The same conclusion was found in Sparck (1933) who described "fjord water" as the factor responsible for the faunal impoverishment of the Greenland coastal fauna. Hopner Petersen (1977) states that the length and produc-

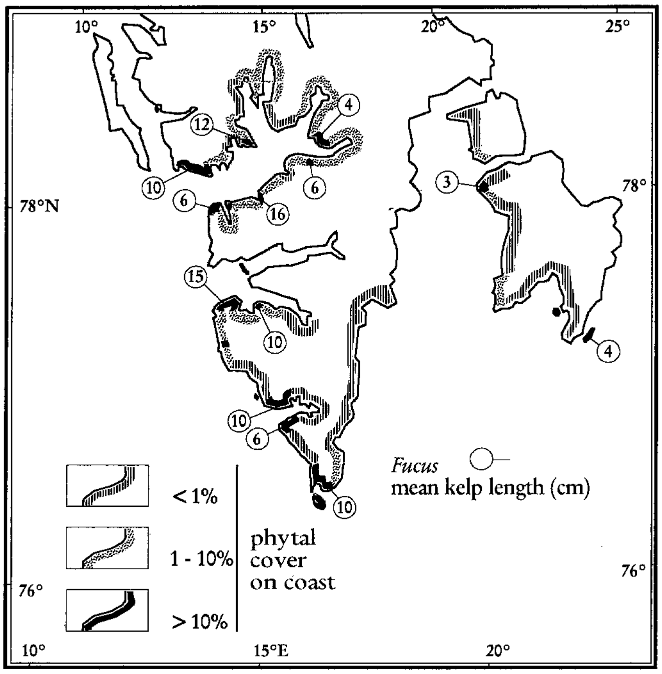

Fig. 4. Occurrence of macrophytes and Fucus distychus mean kelp length at the investigated area. Phytal cover expressed as percentage of a given coast unit covered with littoral macrophytes, August 1988–1990

tion of the summer season are the crucial factors for Greenland intertidal. In the case of the investigated area, longer ice presence (late summer) and the more brackish character of the Spitsbergen east coast are most probably responsible for the striking difference in the intertidal zone inhabitants.

From the biological point of view, the important areas in the Svalbard intertidal are those with the highest biomass and density, that is those in the *Fucus-Balanus* assemblage. These are situated on the coast exposed to the Atlantic ocean at the entrance to the fjords of west Spitsbergen. Surprisingly low numbers of birds forage on the Svalbard littoral. Hardly more than two species (*Calidris maritima* and *Charadrius hiaticula*) are represented by a low number of individuals (Stempniewicz and Weslawski 1992). The scarcity of wading birds on Spitsbergen may be interpreted as an indication that quite rich littoral biocenoses are relatively new in this Arctic archipelago, and are connected with improving climatic conditions.

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